

The University of Chicago

RADIOLARIAN FAUNA OF THE
CABALLOS FORMATION
MARATHON BASIN
TEXAS

A PART OF A DISSERTATION SUBMITTED TO
THE FACULTY OF THE DIVISION OF THE
PHYSICAL SCIENCES IN CANDIDACY FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF GEOLOGY AND PALEONTOLOGY

1937

By
ESTHER ABERDEEN

Private Edition, Distributed by
THE UNIVERSITY OF CHICAGO LIBRARIES
CHICAGO, ILLINOIS

Reprinted from
THE JOURNAL OF PALEONTOLOGY
Vol. 14, March 1940

The University of Chicago

RADIOLARIAN FAUNA OF THE
CABALLOS FORMATION
MARATHON BASIN
TEXAS

A PART OF A DISSERTATION SUBMITTED TO
THE FACULTY OF THE DIVISION OF THE
PHYSICAL SCIENCES IN CANDIDACY FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF GEOLOGY AND PALEONTOLOGY

1937

By
ESTHER ABERDEEN

Private Edition, Distributed by
THE UNIVERSITY OF CHICAGO LIBRARIES
CHICAGO, ILLINOIS

Reprinted from
THE JOURNAL OF PALEONTOLOGY
Vol. 14, March 1940



RADIOLARIAN FAUNA OF THE CABALLOS FORMATION, MARATHON BASIN, TEXAS¹

ESTHER ABERDEEN

Wellesley College, Wellesley, Mass.

ABSTRACT—This study embodies the systematic classification of the Radiolaria of the Devonian Caballos formation and an analysis of their structures in relation to depth of deposition. To this end, a review of the radiolarian literature in North America, method of study, a brief discussion of the physiology, test structures and the basis for classification of the Radiolaria are included. The Radiolaria herein described are remarkably well preserved, many specimens retaining silicified remnants of originally organic structures. Eighteen genera are discriminated and 24 new species are described. Certain features of the shells suggest a shallow habitat for the fauna.

IN 1917, Baker and Bowman reported Radiolaria from the Santiago chert phase of the Caballos novaculite in the Marathon basin. They published photomicrographs showing Radiolaria from this horizon. Subsequently other investigators (P. B. King, 1930 and L. G. Henbest, 1935) have corroborated the occurrence but have not published descriptions of Radiolaria.

A survey of the literature on American radiolarian deposits shows that Radiolaria have been described from one horizon in the Paleozoic and several in the Mesozoic and Cenozoic and have been reported, but not described, from many other horizons. Descriptions of Radiolaria from the following formations have been published: (1) Deep-skill-Normanskill cherts, of Ordovician age (Ruedemann and Wilson, 1935); (2) Franciscan cherts, of Jurassic age (Hinde, 1894); (3) Milwood series in Manitoba, of Upper Cretaceous age (Rüst, 1892); (4) Calvert formation of Maryland, of Miocene age (Martin, 1904); (5) Barbadoes earth deposits, of Miocene age (Ehrenberg, 1875). Radiolaria have been reported, though not described, from the following horizons: (1) Ordovician cherts of Notre Dame Bay, Newfoundland (Sampson, 1923); (2) red cherts in limestone of late Devonian age on the headwaters of the Trinity River, California (Diller, 1913); (3) Leonard and Word formations of Permian age in the Marathon Basin (King, 1930); (4) Jurassic cherts of

the Kanai peninsula (Martin and others, 1912); (5) Jurassic cherts in Oregon (Smith, 1916); (6) Mowry shale, of Upper Cretaceous age, in Wyoming (Rubey, 1929); (7) Arkansas novaculite and Big Fork chert, of probable Devonian age (Henbest, 1936); (8) radiolarian earth in the Eocene section of the Mt. Diablo area, California (Clark and Campbell, 1937). Apparently many radiolarian-bearing horizons are known in North America but little has been done toward describing the fauna.

The fauna described below was studied in thin sections cut from specimens of Santiago member of the Caballos novaculite collected from the hogbacks $1\frac{1}{2}$ miles east of Marathon, Texas. The Caballos novaculite is generally regarded as Devonian in age. The Santiago member is composed of banded chert in which the banding is almost varve-like in appearance. Greenish gray bands of detritus-like material $\frac{1}{4}$ to $\frac{1}{2}$ inch thick alternate with bands of clear chert. The Radiolaria seem to be most abundant in the greenish layers, and specimens described were found principally in these bands. Sections were ground thin enough to transmit light but left sufficiently thick as to show the tests in three dimensions, a procedure which is necessary for the identification of most species.

PHYSIOLOGY AND TEST STRUCTURE OF RADIOLARIA

A brief outline of the physiology and morphology of Radiolaria seems pertinent here.

¹ Part of a dissertation submitted at the University of Chicago in partial fulfillment of the requirements for the degree of Doctor of Philosophy.



FIG. 1.—Sketch map showing location of the Marathon Basin, Texas (modified after King, 1937).

The cytoplasm of a radiolarian (Haeckel, 1887; Earland, 1900; Lankester, 1909) may be differentiated into three parts: (1) a cortical layer of cytoplasm (extracapsular cytoplasm), (2) an intracapsular nucleated cytoplasm, which is separated from the former by (3) a central capsule; the latter marks the division between these two layers and is the feature which distinguishes the Radiolaria from all other Protozoa.

The extracapsular cytoplasm consists of (a) a matrix or assimilative layer which lies immediately next to the central capsule, (b) a *calymma*, or vacuolated layer, frothy in appearance and chiefly flotational in function, and (c) an enveloping membrane, permeable in character, called the *sarcodictyum*. Through all of these extend radiating contractile pseudopodia, which arise in the matrix of the extracapsular layer outside the central capsule.

The central capsule is commonly a single, porous membrane, chitinous, or mucinoid in character, although in one group, *Phaeodaria*, it may be double. Its shape reflects the configuration of the test of the animal. It may be considered a permanent structure, although it is thought to dissolve or rupture more or less during sporulation. It is perforated or contains varied apertures; these apertures (together with the shape and number of shells in the test) constitute one of the bases on which Radiolaria are classified.

The intracapsular cytoplasm is a vacuolated, granular mass, sometimes radially striated, in which are imbedded protein reserves, pigment cells, zooxanthellae (symbiotic protozoans), large crystalline structures and one or more nuclei. The whole is enveloped in a tough outer membrane (*sarcodictyum*), which serves to keep the vacu-

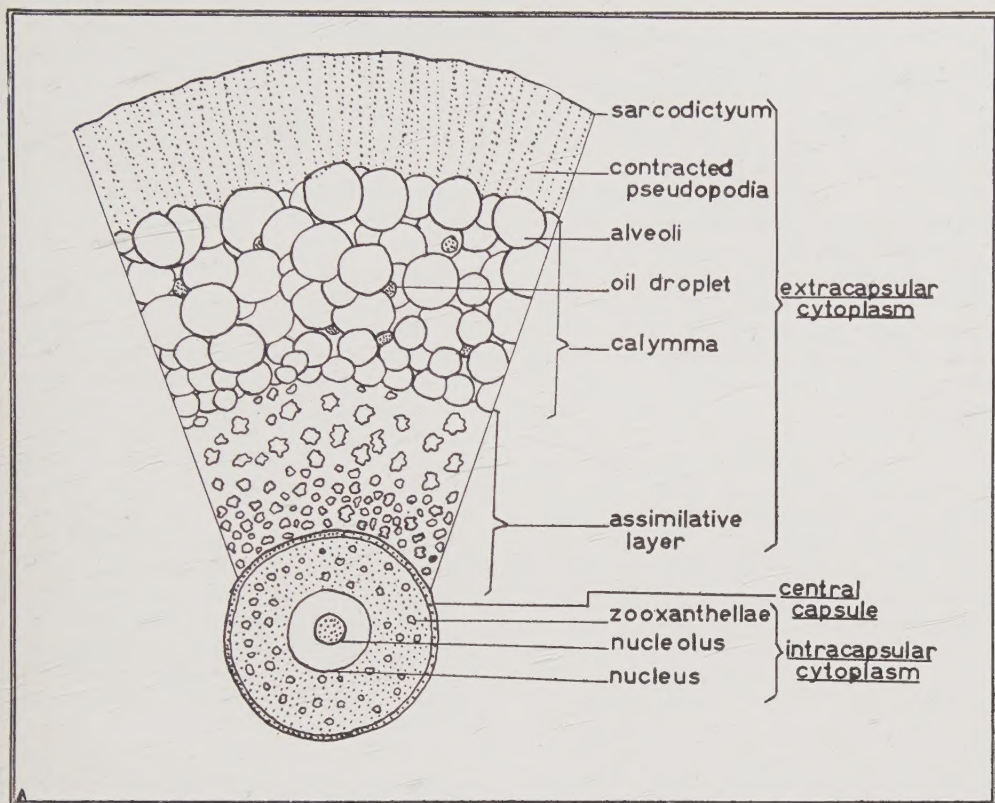


FIG. 2.—Generalized drawing of a radiolarian, showing relationship of various anatomical parts (after Haeckel, 1887).

oles of the calymma together and within the spicular skeletal area.

Each of these various anatomic divisions has its own physiological function. For example, the extracapsular cytoplasm is chiefly concerned with flotation, nutrition, and reception of stimuli. The intracapsular cytoplasm is given over to the process of storage and eventually to reproduction. The central capsule separates these two zones of differing activity.

Radiolarian tests, according to Haeckel, show a greater diversity of form than any other class of the animal kingdom. This diversity invites differentiation into many species. Myriads of forms, known and newly discovered during the Challenger expedition, were classified by Haeckel into the 739 genera and 4,217 species (Haeckel, 1887, p. clxxxviii).

It has been found that various tests are composed of different kinds of material, and shell composition is regarded as fundamental in classification. The same basic shapes may appear in tests composed of different materials. The *Acantharia* skeletons are made of strontium sulphate, the *Spumellaria* and *Nasellaria* of silica, and the *Phaeodaria* of silica combined with an organic compound.

Little is known concerning the formation of the radiolarian test other than that the vacuolated portion of the cytoplasm has the power to deposit silica in the form of perforated and imperforate shells, plates, processes and spicules. There commonly is a great development of siliceous matter, the form of which cannot be referred to the alveolate structures of the protoplasm. Some attempt has been made to trace

skeletal evolution in the *Acantharia* to an axopodial type developed by the hardening of the axial rod, a structure which is found only in the pseudopodia of this class. For other Radiolaria, it is suggested that the formation of the test occurs by fusion of tetrad spicules formed in the calymma by the deposition of silica at the junction of the alveoli. These hypotheses appear to be based on insufficient observational data (Lankester, 1901, p. 131).

The test functions chiefly as a hydrostatic organ. In the *Acanthametridia* it has been found that the spines serve as support for a delicate membrane (interpreted as the sarcodictyum) which confines the alveoli of the calymma (the flotational mechanism). In order to aid in flotation, the spines frequently are flattened or have flanges devised for sustaining and propelling the animal in positions most favorable for transportation in currents. Since these spines are used in classification, their variability adds considerably to the possible number of species.

Three kinds of structural variation are recognized in the tests of Radiolaria: (1) The variation of test structures characteristic of the species; (2) there is what Lankester calls racial somatic dimorphism, representing a response to depth environment in which a given genus or species may develop tests characteristic of deep water or shallow water; and, (3) finally there is a gametic dimorphism of early and adult stages related to reproduction, but such dimorphism has not been proven to result in somatic dimorphism of structure. These various types of dimorphism probably are partly responsible for the very large number of species which have been described.

The somatic dimorphism caused by varying depth environments results in the formation of widely diversified small individuals in warmer surface waters, and large individuals in cold and deep water. This difference in size is reflected in the structure of the test. The tests of the pelagic Radiolaria are delicate and slender, the pores are large, the trabeculae between the pores are thin, and the armature of the spines, such as spathylae and anchors, is diverse. Individuals of the abyssal fauna are characterized by small size and massive structures. Coarse lattice-work, thick trabeculae, small

pores and less conspicuous spines are characteristic (Haeckel, 1887, pp. cliii and cliv).

Paleontologic significance of anatomy and test structure.—In the Radiolaria studied, certain anatomical parts appear to have been preserved. In thin section, a great many clear circles were observed, in reflected light, simply as bright spots. In reflected light these areas distinctly show the shadowy outline of the test, capsule and cloudy masses. In some instances a clear circular area is observed enveloping skeletal outlines, suggesting that the calymma might have been preserved despite its fragile character. Under ordinary circumstances, a gelatinous body of such character would not be preserved, and if our interpretations of these structures is correct the condition for preservation of soft parts must have been extraordinarily favorable. Silica gel and soft organic ooze collecting on a sea floor would probably be an ideal medium in which Radiolaria could settle without being fragmented. It is suggested that the calymma could be preserved under the following condition: The semipermeable membrane (Sarcodictyum) might allow silica rich waters to permeate the whole cytoplasm, and serve at the same time to exclude the organic ooze into which the animal settled. Photomicrographs of specimens oriented as found in the rock (pl. 1, figs. 1–3) show that the organic material settled and was compacted slightly around some specimens. The cytoplasm of the organism might thus become saturated with silica until the concentration within the organism equalled that of the surrounding medium at which point the whole might become solidified, thus preserving the soft organic structures. Evidence supporting this hypothesis is seen in some sections viewed under crossed nicols; the clear zones show coarse, radially-fibrous structures in contrast to the much finer fibrous structure of the matrix. The fact that some specimens do not show clear circles enveloping them suggests that those forms may have become partly disintegrated while settling through the water. Thus, it seems possible for some specimens to be preserved encased in their original gelatinous calymma whereas others are found without them.

The somatic response to depth reflected in dimorphism of test structure within one

genus is suggested as most valuable from the paleontological standpoint. Since the test structures of various species reflect the depth at which they float (thin and delicately spined forms for the surficial water, and thick, finely perforated, stout-spined forms for greater depth) the type of structure suggests the particular depth environment in which the species lived. Fossil fauna showing a mixture of both deep water forms and shallow water forms can be interpreted only as accumulating in deep waters; conversely, formations showing fauna entirely shallow water in their characteristics, can be interpreted as accumulating in shallow waters. Also surficial forms are more completely at the mercy of the surface currents than the deeper water species, and therefore may be floated into various environments.

Caballos fauna.—Eighteen genera are recognized in the Santiago chert, and 24 new species are described. Careful comparison with descriptions of European Paleozoic fauna yields no identical forms. The species *Stylosphaera quasiobtusum* n. sp. shows similarity to a species described by Hinde from the Tamworth series (Devonian) of Australia.

The Radiolaria of the Caballos formation are characterized by (a) slender, ridged or

keeled spines, (b) large pores, (c) very thin connecting bars between the several shells of a test, and (d) delicately latticed shells. These characteristics in modern Radiolaria indicate shallow water not deeper than the pelagic zone.

Recently an attempt was made by Ruedemann to estimate the depth of deposition for the fossil Radiolaria from a study of depth ranges recorded for the same genera in modern seas (Ruedemann, 1935). He concluded that mixed fauna of shallow and deep water forms must have been deposited at depths no less than the greatest depth inhabited in life by the deep water forms. A similar comparison with modern forms has been made here in an attempt to secure information concerning depth of deposition for the Caballos formation. This study shows that almost every modern genus has both shallow and deep water species. In the fossil fauna four genera are represented by only surface dwelling species, and two genera are represented by only deep water species. These data might be interpreted to indicate that this fauna should be considered a deep water one, since it contains some genera found only in depths. But since great variation in depth range is found in modern species, interpretation of the environment for fossil species by analogy is not neces-

TABLE 1.—DEPTH RANGES FOR MODERN SPECIES WHOSE GENERA ARE REPRESENTED IN THE CABALLOS NOVACULITE²

Genera present in Santiago chert	Author of Genus	Depth Range of Modern Species of same Genus
1. <i>Cenosphaera</i>	Ehrenberg	Surface and depths to 2,750 fathoms
2. <i>Carposphaera</i>	Haeckel	Surface and depths to 2,600 fathoms
3. <i>Thecosphaera</i>	Haeckel	Surface (most species) and few at depths to 2,900 fathoms
4. <i>Rhodospaera</i>	Haeckel	1 species, depth 2,900 fathoms
5. <i>Plegmosphaera</i>	Haeckel	8 species, all surface
6. <i>Spongoplegma</i>	Haeckel	1 species, 1,950 fathoms
7. <i>Xiphostylus</i>	Haeckel	15 species, 5 surface, others various depths to 4,475 fathoms
8. <i>Stylosphaera</i>	Ehrenberg	16 species, 3 fossil, 11 deep water and 5 surface
9. <i>Staurosphaera</i>	Haeckel	16 species, 1 fossil, 10 deep water to 3,000 fathoms, 1 surface
10. <i>Staurostylus</i>	Haeckel	
11. <i>Staurodoras</i>	Haeckel	4 species, 3 fossil
12. <i>Hexastylus</i>	Haeckel	25 species, 9 surface, 16 deep water
13. <i>Hexastylidium</i>	Haeckel	2 species, surface
14. <i>Hexalonche</i>	Haeckel	25 species, 9 surface, 14 deep water to 4,500 fathoms, 2 fossil
15. <i>Acanthosphaera</i>	Ehrenberg	31 species, 15 surface, 14 deep water to 4,475 fathoms, 2 fossil
16. <i>Heliosphaera</i>	Haeckel	14 species known, 8 surface, 16 depths to 4,475 fathoms
17. <i>Haliomma</i>	Ehrenberg	33 species known, 19 surface, 11 depths to 2,900 fathoms, 3 fossil
18. <i>Astrophacus</i>	Haeckel	7 species known, 3 surface, 4 depths to 4,475 fathoms

² Compiled from Haeckel, 1887.

sarily reliable. The best evidence of depth therefore appears to lie in structures of the test.

It is concluded that the Caballos radiolarian fauna may be considered a pelagic group, probably deposited in shallow waters, on the following lines of evidence: (1) their skeletal structures are typical of those forms indigenous to shallow waters; (2) the preservation of such structures of the calymma suggest rapid burial which might best be accomplished in waters of shallow depth, and in soft fine sediment of organic siliceous ooze.

Acknowledgments.—The writer is indebted to Dr. Carey Croneis for suggesting the study of the Caballos cherts, and for the interest, helpful criticism and suggestions given during the course of this study. The writer wishes to acknowledge the courtesy of Dr. C. L. Baker in furnishing samples of the formation studied. Acknowledgment is made to Mrs. Helen Jeanne Plummer for her cooperation in supplying references and samples of Barbadoes earth which served as a basis for preliminary studies. Dr. W. C. Krumbein of the University of Chicago and Dr. L. Sloss, Montana School of Mines gave invaluable assistance in the preparation of photomicrographs.

SYSTEMATIC DESCRIPTIONS

In the classification of the modern Radiolaria, Ehrenberg's pioneer work, done chiefly on fossil forms, has been completely revised. In Haeckel's reports many of Ehrenberg's genera fall into groups based on biological features while others are discarded. Haeckel's classification is largely a biologic one, but genera and species are determined primarily by the structure of the test.

Following Haeckel's classification, the Class Radiolaria is distinguished from all other Sarcodina by the fact that it has a central capsule. Subclasses are established on features of the central capsule, its shape and position of apertures; i.e., forms having a spherical shape without an aperture are called Porulosa; and forms having an oval shape with an aperture at the basal pole are called Osculosa. The so-called Legions are determined (1) by the composition of the test in the Porulosa, those with siliceous tests being called Spumellaria, and those

with strontium sulphate tests, the Acanthometrida; (2) in the Osculosa, Legions are determined by the type of closure for the aperture. A porous plate closes the aperture in Nasellaria, and an operculum and astropyle in the Phaeodaria. Sublegions of Haeckel are determined by the condition of the test: (1) incomplete or wanting, Colodaria; (2) complete or shell-bearing forms, Sphaerellaria. Orders are based on the shape of the test: (1) A test is wanting in the Colloidea; the Beloidea are composed of disarticulated spicules, (2) Sphaeroidea and Prunoidea and other orders are based on the general outline of the tests. Families are based on combinations of features such as (1) the number of shells and spines of an individual test; (2) position of various rings and number of constrictions, or (3) types of aperture. Genera and Species are based on a number of features such as (1) number, length, shape and terminae of spines, (2) presence or absence of spongy shell structures, and (3) their shape, size and distribution of pores.

Students of Radiolaria have generally adopted Haeckel's classifications. Only occasionally have subsequent workers found it necessary to establish new genera, and generally the method of description used for the living forms has been followed. Up to 1900, approximately 15 new fossil genera had been added to the list of genera known to Haeckel. Three were established by Rüst, one by Dryer and 11 by Hinde. This is a surprisingly small number of new genera considering the fact that the number of new species has been enormous.

All specimens described in this paper come from the same locality, hogbacks 1½ miles east of Marathon, Texas, and are from the Santiago chert member in the Caballos novaculite.

SYSTEMATIC DESCRIPTIONS

Class RADIOLARIA

Legion SPUMELLARIA Ehrenberg, 1875

Order COLLODARIA Haeckel, 1881

Family THALLASSICOLLIDAE Haeckel, 1862

Plate 20, figures 1-3

Many specimens appearing as almost clear globules with only faint outlines of the central capsule are considered to be mem-

bers of this family. Usually the calymma is preserved outside the central capsule.

Order SPAERELLARIA Haeckel, 1881
Family LIOSPHERIDAE Haeckel, 1881
Genus CENOSPHERA Ehrenberg, 1854

Liosphaeridae with a single latticed sphere having simple pores (not prolonged in tubuli), and a simple shell cavity (without internal radial beams).

Remarks.—Species are based on shape and distribution of pores.

CENOSPHERA VARIABILIS Aberdeen, n. sp.
Plate 20, figure 17

Test is simple, spherical lattice 0.145 mm in diameter, with lattice bars 0.027 mm in width; pores vary in size from 0.007 to 0.104 mm.

Remarks.—The range in pore size is marked but consistent in all specimens; the larger pores are about twice the size of the smaller ones.

Types.—Syntypes, Walker Mus., Chicago Univ. 44496, no. 2; 44997, no. 9.

CENOSPHERA HEXAGONALIS
Aberdeen, n. sp.
Plate 20, figures 12, 13

Test simple, lattice 0.166 mm in diameter with very thin and delicate lattice bars 0.02 mm in diameter; pores large, 0.06 mm in diameter, and either hexagonal or polygonal in outline.

Remarks.—This species is characterized by polygonal or hexagonal pores, and very thin lattice bars. It is smaller than the average Radiolaria in this fauna. It is similar to, but larger than, *Cenosphaera regularis* Rüst, 1885 (Rüst, 1885, table 1, fig. 5).

Type.—Holotype, Walker Mus., Chicago Univ. 44496, no. 1.

CENOSPHERA SEMIEQUALIS Aberdeen, n. sp.
Plate 20, figures 7, 8

Test simple, spherical lattice of large size with pores only slightly larger than the width of the lattice bars; diameter of test, 0.25 mm.; lattice bars 0.007 mm.; pores vary in size from 0.007 to 0.005 mm.

Remarks.—This species differs from *C. hexagonalis*, n. sp. in larger size of the test and shape of the pores; it differs from *C. variabilis*, n. sp. in size, although the pore

arrangement in both is variable, the lattice bars are slightly thicker in *C. semiequalis*.

Types.—Syntypes, Walker Mus., Chicago Univ. 44538, no. 2; 44997, no. 9.

Family CARPOSPHERIDAE Haeckel, 1881
Genus CARPOSPHERA Haeckel, 1881

Test possesses one medullary (intracapsular) and one cortical (extracapsular) shell, both connected by radial beams piercing the central capsule.

Remarks.—The distance between shells is as great and commonly much greater than the radius of the inner shell. In *Liosphaera*, this distance is less than the radius of the inner shell.

CARPOSPHERA MAGNA Aberdeen, n. sp.
Plate 20, figure 18; plate 21, figures 4, 10

Test consists of two lattice shells one within the other, connected by bars; inner shell separated from outer shell by a distance greater than radius of inner shell; diameter of test, 0.415 mm to 0.362 mm; thickness of outer shell, 0.0166 mm; diameter of inner shell, 0.099 mm; length of connecting bars, 0.133 mm; average number of connecting bars visible, eight.

Remarks.—This species is characterized by very small inner shells. The length of the connecting bars is correspondingly long. The test generally is large.

Types.—Syntypes, Walker Mus., Chicago Univ. 44493, no. 8; 44545, no. 8; 44535, no. 2.

CARPOSPHERA EQUALIS Aberdeen, n. sp.
Plate 20, figures 4, 5

Test of two latticed shells, one within the other, connected by bars; inner shell separated from outer shell by a distance equal to diameter of inner shell; diameter of test, 0.282 mm to 0.362 mm; thickness of outer shell, 0.106 mm; diameter of inner shell, 0.083 to 0.11 mm; length of bars, about 0.09 mm.

Remarks.—The latticed shell in the center has pores 0.008 mm in diameter which are irregularly shaped. *C. equalis* differs from *C. magna* in its smaller size and larger inner sphere.

Types.—Syntypes, Walker Mus., Chicago Univ. 44545, no. 7; 44543, no. 4.

Family THECOSPHAERIDAE Haeckel, 1881
Genus THECOSPHAERA Haeckel, 1881

Test with two medullary (intracapsular) shells and one cortical (extracapsular) shell; distance between two inner shells less than between inner and outer shells.

THECOSPHAERA HEXPENETRATA

Aberdeen, n. sp.

Plate 21, figure 16

Test consists of three concentric latticed shells; inner two closely spaced, but are separated widely from the outer shell; bars in varying numbers extend from the outer shell to the first inner shell, but there are only six bars which penetrate from the outer shell into the central shell; diameter of test 0.39 mm; thickness of outer shell 0.06 mm; diameter of penultimate shell, 0.113 mm; diameter of innermost shell, 0.08 mm; thickness of bars, 0.026 mm.

Remarks.—This species differs from *T. sexarchica* Rüst (Rüst, 1891–92, p. 137) in that the latter has six bars which extend from the outer shell to the innermost shell. No other supporting bars are present.

Type.—Holotype, Walker Mus., Chicago Univ. 44536, no. 2.

Genus RHODOSPHAERA Haeckel, 1881

Thecosphaeridae with one medullary (intracapsular shell and two cortical (extracapsular) shells. *Rhodospaera* differs from *Thecosphaera* in that the outer shells lie closer together. The distance between these two outer shells is much smaller than the radius of the inner shell. The inner shells are connected to the outer ones by radial bars.

RHODOSPHAERA sp. indet.

Plate 20, figure 10

The specimen referred to this genus shows three concentric shells; the inner separated from the two outer ones by a distance greater than the radius of the inner shell. The radial beams in the specimen described are indicated only between the inner shell and the second extracapsular shell.

Type.—Figured specimen, Walker Mus. Chicago Univ. 44547, no. 2.

Family PLEGMOSPHAERIDAE Haeckel, 1881
Genus PLEGMOSPHAERA Haeckel, 1881

Test consisting of hollow sphere of spongy framework without a medullary shell in the central cavity; wall composed of loose or dense spongy wicker-work; simple lattices may or may not be present as supports for the spongy framework either on inner or outer surface.

PLEGMOSPHAERA SPICULATA

Aberdeen, n. sp.

Plate 21, figure 3

Test consists of spherical shell of thick and spongy silica; outer rim of shell latticed, and separated from thicker inner spongy shell by numerous slender spicules; diameter of test, 0.498 mm; diameter of central space, 0.315 mm; inner surface of spongy framework finely porous; spicules are characteristic of the species.

Type.—Holotype, Walker Mus., Chicago Univ. 44532, no. 7; paratype, Walker Mus., Chicago Univ. 44497, no. 4.

Genus SPONGOPLEGMA Haeckel, 1881

Plegmosphaeridae is spongy framework enclosing in center a single latticed medullary shell.

SPONGOPLEGMA BREVISPHAERA

Aberdeen, n. sp.

Plate 21, figure 17

Test consists of spongy shell diameter of which is 0.5 mm; shell thickness, 0.08 mm; within spongy external shell is a central area, 0.30 mm; in the middle of which is small lattice sphere, 0.08 mm in diameter.

Remarks.—The spongy network is less than half as wide as in *S. longispina*. The thinner spongy shell characterizes the new species.

Types.—Syntypes, Walker Mus., Chicago Univ. 44543, no. 3; 44538, no. 1.

SPONGOPLEGMA LONGISPINOSA

Aberdeen, n. sp.

Plate 20, figure 6

Test consists of spongy external shell 0.68 mm in diameter, and 0.16 mm in thickness, within which is smaller lattice sphere 0.12 mm in diameter and 0.005 mm in thickness; bars 0.01 mm in diameter and 0.11 mm long

connect this inner sphere with the outer sphere.

Remarks.—Within the spongy shell long spines extend from the innermost spongy portion of the external shell to support the outer layer of spongy lattice, and are characteristic of this species.

Types.—Syntypes, Walker Mus., Chicago Univ. 44998, no. 13; 44546, no. 5.

Family STYLOSPHAERIDAE Haeckel, 1881

Genus XIPHOSTYLUS Haeckel, 1881

Test with one single lattice and two free spines of variable size and form.

Remarks.—This genus differs from *Xiphosphaera* in size and form of spines, which are equal in size in the latter.

XIPHOSTYLUS INCLINATUS Aberdeen, n. sp.
Plate 21, figures 7, 8

Test consists of single lattice sphere, 0.19 mm in diameter and 0.01 mm in thickness with two unequal spines opposite each other, shorter spine is 0.14 mm in length and 0.05 mm in width at the base; the longer spine is 0.19 mm in length and 0.06 mm in width at the base; lattice of shell has very minute uniform pores 0.004 mm in diameter.

Remarks.—This species differs from *X. asper* Rüst (Rüst, 1891–1892, pl. 7, fig. 6 and pl. 10, fig. 7) from the lower Silurian phosphorite of Cambrière, in having longer spines. It differs from *X. ardea* Rüst from the lower Carboniferous in the Harz in that *X. ardea* has a group of spines.

Types.—Syntypes, Walker Mus., Chicago Univ. 44548, no. 1; 44494, no. 1.

Genus STYLOSPHAERA Ehrenberg, 1847

Stylosphaeridae with two concentric latticed spheres and two free spines of equal size and similar form. The two shells are connected by radial beams piercing the wall of the central capsule.

STYLOSPHAERA QUASIOBTUSA

Aberdeen, n. sp.

Plate 21, figure 5

Test consists of two concentric latticed spheres of which the outer one is 0.2 mm in diameter and 0.01 mm in thickness; the inner one, 0.08 mm in diameter, thickness undeterminable; two bars in line with the spines support the inner sphere respectively

0.05 mm in length and 0.01 mm in width; two stout spines opposite each other, equal in size and length extending from the surface of the outer sphere, have a length of 0.18 mm and width at the base of 0.05 mm.

Remarks.—*Stylosphaera* occurs in the Tamworth series (Devonian) of Australia. The species here described resembles *S. obtusa* Hinde from the Tamworth horizon (Hinde, 1899, p. 45), but differs from it in (1) shorter spines, (2) lattice sphere twice as large, and (3) thinner support for inner sphere.

Types.—Syntypes, Walker Mus., Chicago Univ. 44544, no. 5b; 44998, no. 2.

Family STAUROSPHAERIDAE Haeckel, 1881

Genus STAUROSTYLUS Haeckel, 1881

Tests are single latticed spheres with four spines in pairs of unequal length.

STAUROSTYLUS VARISPINATUS

Aberdeen, n. sp.

Plate 20, figure 19

Test consists of a single spherical shell (somewhat fractured in figured specimen) 0.20 mm in diameter and 0.006 mm in thickness; spines unequal in size and definitely keeled, probably paired; longer spine, 0.18 mm in length and 0.05 mm in width at base with pointed end; shorter spine, 0.07 mm in length and 0.04 mm broad at base with rounded end; latticed sphere seems to be evenly porous, pores being 0.01 mm in diameter.

Type.—Holotype, Walker Mus., Chicago Univ. 44997, no. 8.

Genus STAUROSPHAERA Haeckel, 1881

Staurosphaeridae with single latticed sphere and four equal spines lying in the same plane at right angles to each other.

STAUROSPHAERA ROTUNDA Aberdeen, n. sp.
Plate 20, figure 11

Test consisting of a single latticed sphere 0.16 mm in diameter and 0.005 mm in thickness; pores of test range in size from 0.004 mm to 0.013 mm; spines approximately 0.06 mm in length and are blunt.

Remarks.—The size of the latticed sphere is diagnostic. The bluntness of the spine suggests that they may have been longer, but the size compared with other *Staurosphaera* is smaller and more obviously rounded.

Type.—Holotype, Walker Mus., Chicago Univ. 44548, no. 5.

Genus *STAURODORAS* Haeckel, 1881

Staurosphaeridae with solid, spongy, spherical shells and four simple cortical spines.

STAURODORAS BREVISPINOSA

Aberdeen, n. sp.

Plate 21, figure 11

Test spongy, spherical, 0.12 mm in diameter; pores on the surface exceedingly minute, about 0.002 mm in diameter; thickness of shell undeterminable; four spines present, short, about 0.02 mm in length.

Type.—Holotype, Walker Mus., Chicago Univ. 44546, no. 6.

Family *CUBOSPHAERIDAE* Haeckel, 1881

Genus *HEXASTYLUS* Haeckel, 1881

Cubosphaeridae with one simple latticed shell and six simple, equal spines.

HEXASTYLUS BASIPOROSUS Aberdeen, n. sp.
Plate 21, figures 6, 9, 13

Test single latticed sphere, 0.09 mm in diameter and 0.01 mm thick with six spines of equal length; spines are 0.06 mm in length, 0.02 mm wide at the base, and have keels on four sides; latticed bars are 0.002 mm thick, and the pores vary from 0.004 mm to 0.02 mm in size. Larger pores seem to be arranged about the base of the spines; this feature characterizes the species.

Types.—Syntypes, Walker Mus., Chicago Univ., 44495, no. 2; 44546, no. 5a; 44549, no. 10; 44537, no. 2.

Genus *HEXASTYLIDIUM* Haeckel, 1881

Cubosphaeridae with one simple latticed sphere and three unequal pairs of spines; two opposite spines of each pair equal.

HEXASTYLIDIUM VARIATUM Aberdeen, n. sp.
Plate 21, figure 14

Test consisting of a single latticed shell,

EXPLANATION OF PLATE 20

All specimens illustrated are from the Caballoš formation, Marathon, Texas; all figures $\times 93$, except fig. 18, which is $\times 18$.

- FIGS. 1-3—*Thalassicollidae*, family. 1, Figured specimen, Walker Mus., Chicago Univ. 44544, no. 5. 2, Figured specimen, Walker Mus., Chicago Univ. 44544, no. 4. 3, Figured specimen, Walker Mus., Chicago, Univ. 44544. Specimens showing calymma preserved and compaction of organic ooze around organism. (p. 132)
- 4, 5—*Carpasphaera equalis* Aberdeen, n. sp. 4, Syntype, Walker Mus., Chicago, Univ. 44546, no. 8. 5, Syntype, Walker Mus., Chicago Univ., 44532, no. 6. (p. 133)
- 6—*Spongoplegma longispinosa* Aberdeen, n. sp. Syntype, Walker Mus., Chicago Univ. 44546, no. 5. (p. 134)
- 7, 8—*Cenosphaera semiequalis* Aberdeen, n. sp. Syntype, Walker Mus., Chicago Univ. 44538, no. 2. 8, Syntype, Walker Mus., Chicago Univ. 44998, no. 9. (p. 133)
- 9—*Hexalonche* sp. indet. Figured specimen, Walker Mus., Chicago Univ. 44997, no. 12. (p. 137)
- 10—*Rhodospaera*, sp. indet. Figured specimen, Walker Mus., Chicago Univ. 44547, no. 2. (p. 134)
- 11—*Staurosphaera rotunda* Aberdeen, n. sp. Holotype, Walker Mus., Chicago Univ. 44548, no. 5. (p. 135)
- 12, 13—*Cenosphaera hexagonalis* Aberdeen, n. sp. Holotype, Walker Mus., Chicago Univ. 44496, no. 1. 13, Paratype, Walker Mus., Chicago Univ. 44995, no. 5. (p. 133)
- 14—*Heliosphaera macrospinosa* Aberdeen, n. sp. Holotype, Walker Mus., Chicago Univ. 44498, no. 1. (p. 138)
- 15—*Astrophacus cingulatus* Aberdeen, n. sp. Holotype, Walker Mus., Chicago Univ. 44996, no. 4. (p. 139)
- 16, 20—*Italiomma perfecta* Aberdeen, n. sp. 16, Syntype, Walker Mus., Chicago Univ. 44532, no. 6. 20, Syntype, Walker Mus., Chicago Univ. 44546, no. 8. (p. 138)
- 17—*Cenosphaera variabilis* Aberdeen, n. sp. Syntype, Walker Mus., Chicago Univ. 44496, no. 2. (p. 133)
- 18—*Carpasphaera magna* Aberdeen, n. sp. Syntype, Walker Mus., Chicago Univ. 44493, no. 8. (p. 133)
- 19—*Staurostylus varispinatus* Aberdeen, n. sp. Holotype, Walker Mus., Chicago Univ. 44997, no. 8c. (p. 135)
- 21—*Acanthospaera microspinosa* Aberdeen, n. sp. Holotype, Walker Mus., Chicago Univ. 44534, no. 6. (p. 138)
- 22—*Heliosphaera alternata* Aberdeen, n. sp. Holotype, Walker Mus., Chicago Univ. 44545, no. 7. (p. 138)

0.1 mm in diameter, coarsely porous, with three pairs of unequal spines; longer pair apparently represented by only one spine, which is thicker and longer than the others, being 0.14 mm in length and 0.016 mm in diameter; second pair of spines shorter, thicker and sharply pointed being 0.04 in length and 0.02 mm wide at the base; smaller spine very slender being 0.14 mm in length and 0.006 mm in width; lattice pores irregularly polygonal in shape varying from 0.115 mm to 0.01 mm.

Type.—Holotype, Walker Mus., Chicago Univ., 44545, no. 11.

Genus HEXALONCHE Haeckel, 1881

Cubosphaeridae with two concentric shells and six simple spines of equal size.

HEXALONCHE sp. indet.

Plate 20, figure 9

Test consists of two concentric latticed spheres with three sets of paired spines; diameter of outer shell, 0.17 mm; thickness, 0.005 mm; diameter of inner shell, 0.14 mm;

thickness, 0.002 mm; spines are 0.1 mm in length and 0.12 mm in width at the base; outer sphere finely perforated, pores about 0.007 mm in size.

Types.—Figured specimens, Walker Mus., Chicago Univ. 44997, no. 12; 44537, no. 6.

Family ASTROSPHAERIDAE Haeckel, 1881
Genus ACANTHOSPHAERA Ehrenberg, 1858

Test having one simple lattice sphere, covered with simple, uniform, radial spines.

ACANTHOSPHAERA DODECASPINOSA

Aberdeen, n. sp.

Plate 21, figures 2, 15, 18

Test consisting of single lattice sphere, 0.16 mm in diameter and 0.004 mm in thickness; 10 to 12 equal spines radiating from various points on the sphere having a length of 0.10 mm and width of 0.02 mm, and are slightly keeled at the base. Lattice shows rather small pores varying in size from 0.115 mm to 0.01 mm; no definite arrangement of pores is visible.

Types.—Syntypes, Walker Mus., Chicago Univ., 44535, nos. 3, 4; 44548, no. 11.

EXPLANATION OF PLATE 21

All specimens illustrated are from the Caballos formation, Marathon, Texas; all figures $\times 93$.

- FIGS. 1—*Spongoplegma longispinosa* Aberdeen, n. sp. Syntype, Walker Mus., Chicago Univ. 44998, no. 13. (p. 134)
2, 15, 18—*Acanthosphaera dodecaspinosa* Aberdeen, n. sp. 2, Syntype, Walker Mus., Chicago Univ. 44538, no. 4. 15, Syntype, Walker Mus., Chicago Univ. 44548, no. 11, 18, Syntype, Walker Mus., Chicago Univ. 44535, no. 3. (p. 137)
3—*Plegmosphaera spiculata* Aberdeen, n. sp. Holotype, Walker Mus., Chicago Univ. 44532, no. 7. (p. 134)
4, 10—*Carposphaera magna* Aberdeen, n. sp. 4, Syntype, Walker Mus., Chicago Univ. 44545, no. 8. 10, Syntype, Walker Mus., Chicago Univ. 44535, no. 2. (p. 133)
5—*Stylosphaera quasiobtusa* Aberdeen, n. sp. Syntype, Walker Mus., Chicago Univ. 44998, no. 2. (p. 135)
6, 9, 13—*Hexastylus basiporosus* Aberdeen, n. sp. 6, Syntype, Walker Mus., Chicago Univ. 44546, no. 5a. 9, Syntype, Walker Mus., Chicago Univ. 44542, no. 4a. 13, Syntype, Walker Mus., Chicago Univ. 44495, no. 2. (p. 136)
7, 8—*Xiphostylus inclinatus* Aberdeen, n. sp. 7, Syntype, Walker Mus., Chicago Univ. 44494, no. 11. 8, Syntype, Walker Mus., Chicago Univ. 44548, no. 1. (p. 135)
11—*Staurodoras brevispinosa* Aberdeen, n. sp. Holotype, Walker Mus., Chicago Univ. 44546, no. 6. (p. 136)
12—*Acanthosphaera hirsuta* Aberdeen, n. sp. Holotype, Walker Mus., Chicago Univ. 44543, no. 5. (p. 138)
14—*Hexastylidium variatum* Aberdeen, n. sp. Holotype, Walker Mus., Chicago Univ. 44545, no. 11. (p. 136)
16—*Thecosphaera hexpenetrata* Aberdeen, n. sp. Holotype, Walker Mus., Chicago Univ. 44536, no. 2. (p. 134)
17—*Spongoplegma brevisphaera* Aberdeen, n. sp. Syntype, Walker Mus., Chicago Univ. 44542, no. 3. (p. 134)
19—*Acanthosphaera grandispinosa* Aberdeen, n. sp. Holotype, Walker Mus., Chicago Univ. 44547, no. 3. (p. 138)

ACANTHOSPHAERA MICROSPINOSA

Aberdeen, n. sp.

Plate 20, figure 21

Test consisting of single latticed sphere 0.18 mm in diameter and about 0.01 mm in thickness; surface covered with many very short, slender spines 0.102 mm to 0.03 mm in length, all of which are about 0.01 mm wide at the base. Lattice of the test is irregularly perforated, the pores being irregularly polygonal in shape, and varying from 0.01 mm to 0.004 mm in diameter.

Type.—Holotype, Walker Mus., Chicago Univ. 44535, no. 6.

ACANTHOSPHAERA HIRSUTA Aberdeen, n. sp.
Plate 21, figure 12

Test consisting of single latticed shell, 0.18 mm in diameter and about 0.006 mm in thickness; slender spines, 0.14 mm in length and ranging from 0.004 to 0.006 mm in diameter cover the surface of the sphere.

Remarks.—The numerous slender spines surrounding the test produce a hirsute appearance differentiating it from other species of *Acanthosphaera*.

Type.—Holotype, Walker Mus., Chicago Univ. 44543, no. 5.

ACANTHOSPHAERA GRANDISPINOSA

Aberdeen, n. sp.

Plate 21, figure 19

Test consisting of single latticed sphere, 0.2 mm in diameter; shell thickness and pore size undeterminable; long, tapering spines 0.24 mm in length and 0.02 mm in diameter are found over the surface. The unusual length of the spines is characteristic.

Type.—Holotype, Walker Mus., Chicago Univ. 44547, no. 3.

Genus HELIOSPHAERA Haeckel, 1862

Astrosphaeridae with one simple lattice sphere; covered with simple radial spines of two different kinds; larger spines separated by smaller spines.

HELIOSPHAERA MACROSPINOSA

Aberdeen, n. sp.

Plate 20, figure 14

Test a single latticed sphere, 0.12 mm in diameter and 0.01 mm in thickness; numerous spines of two sizes; larger spines are

short, stout, sharp; 0.06 mm in length, and 0.03 mm in thickness at the bases; secondary spines about 0.04 mm in length and 0.01 mm in breadth; lattice coarse; pores about twice as wide as lattice bars; diameter varies from 0.01 mm to 0.02 mm.

Remarks.—The large stout spines and coarse lattice are characteristic of the species.

Type.—Holotype, Walker Mus., Chicago Univ. 44498, no. 1.

HELIOSPHAERA ALTERNATA

Aberdeen, n. sp.

Plate 20, figure 22

Test consisting of single latticed sphere 0.18 mm in diameter and 0.01 mm in thickness; there are two groups of spines present. The longer spines are long, slender tapering to a point being variable in number, 0.14 mm in length and about 0.12 mm in width at the base. They are separated by smaller short ones, 0.02 mm in length and about 0.001 mm in diameter; lattice pores are polygonal, varying in size from 0.002 mm to 0.01 mm in diameter; and are much larger than the thickness of the lattice bars.

Type.—Holotype, Walker Mus., Chicago Univ. 44545, no. 7.

Genus HALIOMMA Ehrenberg, 1838

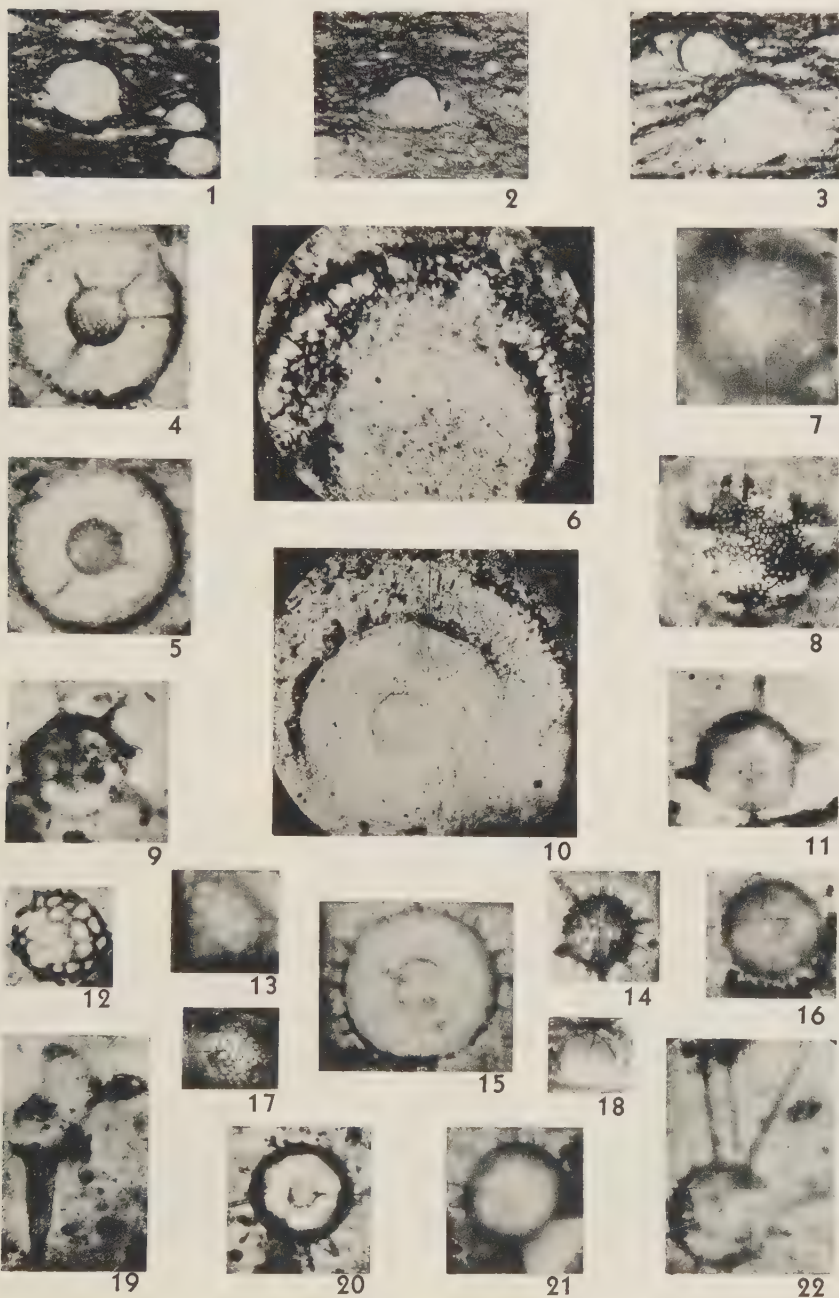
Astrosphaeridae with one medullary (intracapsular) and one cortical (extracapsular) shell, which are connected by radial beams, piercing the central capsule. Shell surface covered with uniform simple radial spines of the same kind.

HALIOMMA PERFECTA Aberdeen, n. sp.

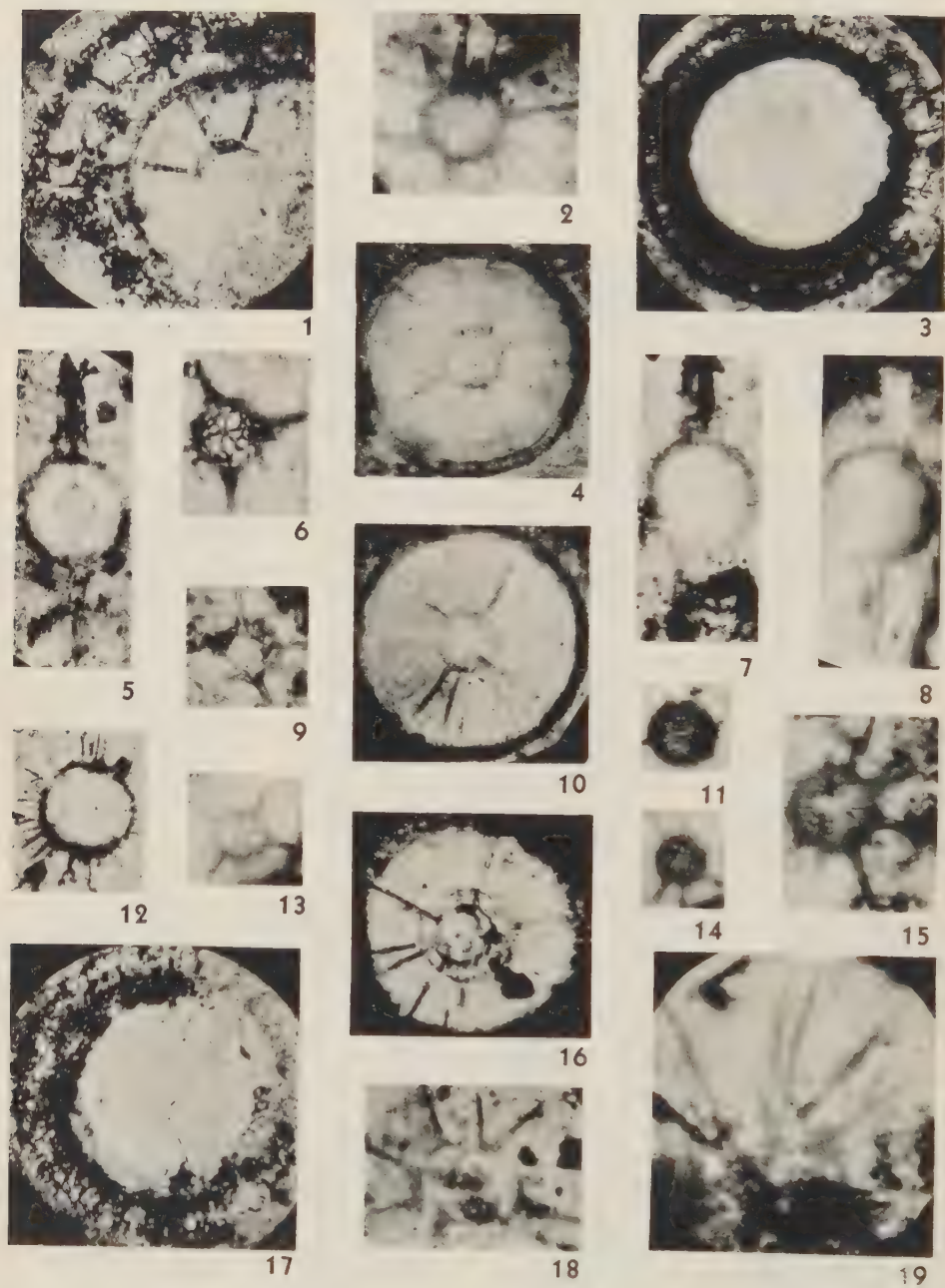
Plate 20, figures 4, 6, 20

Test consisting of two latticed concentric spheres of which the outer one is 0.18 mm to 0.20 mm in diameter, and about 0.01 mm in thickness; inner sphere about 0.04 mm in diameter and 0.001 mm in thickness being supported by six bars 0.005 mm in thickness and 0.05 mm long; spines short, about 0.02 mm to 0.03 mm in length and 0.002 mm in width at base; lattice pores of outer sphere about 0.01 mm in diameter, polygonal, about three times wider than the intervening areas; pores on inner shell undeterminable.

Types.—Syntypes, Walker Mus., Chi-



Aberdeen, Devonian Radiolaria



Aberdeen, Devonian Radiolaria

cago Univ. 44532, no. 6; 44537, no. 9; 44546, no. 8.

Order DISCOIDEA Haeckel, 1862

Family PHACODISCIDAE Haeckel, 1881

Genus ASTROPHACUS Haeckel, 1881

Phacodiscidae with double medullary shell and numerous (20 or more) simple radial spines on the margin of the disc, commonly with a variable number and an irregular disposition of the spines.

ASTROPHACUS CINGULATUS

Aberdeen, n. sp.

Plate 20, figure 15

Test consisting of two shells, the outer one being 0.32 mm in diameter and 0.005 mm in thickness. Apparently the center sphere was supported by bars, but only the remnant of one is visible. The even arrangement of the spines around the periphery and the exact number appearing on either side of the slide suggests that the outer shell was discoid in character with a spiny periphery. The spines are all 0.02 mm in length and 0.01 mm wide at the base. They are short and acuminate. No lattice is visible. The inner shell is spherical.

Type.—Holotype, Walker Mus., Chicago Univ. 44996, no. 4.

REFERENCES

- BAKER, C. L., and BOWMAN, W. F., 1917, Geologic exploration of the southeastern Front Range of Trans-Pecos, Texas: *Univ. Texas Bull.* 1753, pp. 93–101.
- CLARK, B. L., and CAMPBELL, A. S., 1938, Radiolarian earth in the Eocene series of Mt. Diablo area, middle California: *Geol. Soc. America Proc.* 1937, p. 74.
- DILLER, J. S., 1903, The Klamath mountain section, California: *Am. Jour. Sci.*, 4th ser., vol. 15, pp. 342–344.
- , 1896, Geological reconnaissance in northwest Oregon: *U. S. Geol. Survey, 17th Ann. Rept.*, pt. 1, p. 470.
- EHRENBERG, C. L., 1875, *Fortsetzung der Microgeologischen Studien als gesamt Übersicht der mikroskopischer Paleontologie gleichartig analysierter Gebirgsarten der Erde, mit specialer Rücksicht auf der Polycystinen-Mergel von Barbadoes*, Berlin.
- HAECKEL, ERNEST, 1887, The Radiolaria: *Challenger Expedition Reports*, vol. 18, pts. 1 and 2.
- HENBEST, L. B., 1936, Radiolaria in the Arkansas novaculite, Caballos novaculite, and Bigfork chert: *Jour. Paleontology*, vol. 10, pp. 76–78.
- HINDE, G. J., 1894, Note on radiolarian cherts from Angel Island, California: *California Univ., Dept. Geol. Sci., Bull.*, vol. 1, pp. 235–240.
- , 1899, On the radiolaria in the Devonian rocks of New South Wales: *Geol. Soc. London Quart. Jour.*, vol. 40, pp. 38–50.
- JUKES-BROWNE, A. J., and HARRISON, J. B., The geology of the Barbadoes: *Geol. Soc. London Quart. Jour.*, vol. 47, p. 197.
- KING, P. B., 1930, Geology of the Glass Mountains: *Texas Univ. Bull.* 3038, p. 64.
- , 1937, Geology of the Marathon Region, Texas: *U. S. Geol. Survey Prof. Paper* 187.
- LANKESTER, E. R., 1909, *Treatise on Zoology*: pt. 1, fasc. 1, A. C. Black, London.
- MARTIN, C. D., JOHNSON, B. L., and GRANT, U. S., 1912, Geology and mineral resources of the Kenai peninsula, Alaska: *U. S. Geol. Survey Bull.* 587, p. 61.
- MARTIN, G. C., 1904, Radiolaria: *Maryland Geol. Survey, Miocene*, pp. 447, 459; pls. 130, 72–77.
- RUBEX, G. C., 1929, Origin of the siliceous Mowry shale of Black Hills region: *U. S. Geol. Survey Prof. Paper* 154-D, pp. 154–179.
- RUEDEMANN, R., and WILSON, T. Y., 1936, Eastern New York Ordovician cherts: *Geol. Soc. America Bull.*, vol. 47, pp. 1535–1586.
- RÜST, R. D., 1884–85, Beiträge zur Kenntniss der fossilen Radiolarien aus Gesteinen des Jura: *Paleontographica*, vol. 31, tab. 1, fig. 5.
- , 1892, Radiolaria from the Pierre formation of northwestern Manitoba: *Canadian Geol. Survey, Contributions to Micropaleontology*, pt. iv, pp. 101–111.
- , 1891–1892, Beiträge zur Kenntniss der fossilen Radiolarien aus Gesteinen der Trias und der Paleozoischen Schichten: *Paleontographica*, vol. 38, pl. 9, fig. 6, and pl. 10, fig. 7.
- SAMPSON, E., 1923, The ferruginous chert formations of Notre Dame Bay, Newfoundland: *Jour. Geology*, vol. 31, pp. 571–598.
- SMITH, W. D., 1916, Notes on radiolarian chert in Oregon: *Am. Jour. Sci.*, 4th ser., vol. 42, pp. 299–300; p. 504.
- TYRELL, J. B., 1890, Foraminifera and Radiolaria from the Cretaceous of Manitoba: *Royal Soc. Canada Trans.*, vol. 8, pp. 111–115.

